
**FINAL
Opalite Mine
Site Investigation Report
Malheur County, Oregon**

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Prepared for:

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List of Abbreviations and Acronyms

Acronym	Definition
AGP	acid generating potential
AMD	acid mine drainage
ARD	acid rock drainage
COIs	contaminants of interest
COPCs	contaminants of potential concern
CPEC	contaminant of potential ecological concern
CSM	conceptual site model
DEQ	Oregon Department of Environmental Quality
E & E	Ecology and Environment, Inc.
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
°F	degrees Fahrenheit
GPS	Global Positioning System
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
ODFW	Oregon Department of Fish and Wildlife
ORNHIC	Oregon Natural Heritage Information Center
PRGs	preliminary remediation goals
QA	quality assurance
RBCs	risk-based concentrations
RI	remedial investigation
SI	site investigation
SLVs	screening level values
SPLP	synthetic precipitate leaching procedure
TAL	Target Analyte List
Weston	Weston Solutions, Inc.
XRF	X-ray fluorescence

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Introduction

Ecology and Environment, Inc. (E & E), under contract with the Oregon Department of Environmental Quality (DEQ), has prepared this site investigation (SI) report to present the purpose, methods, and conclusions of this SI of sediment, surface water, fish tissue, soil, and road material contamination at the Opalite Mine site in Malheur County, Oregon (Figure 1). The Opalite Mine SI was performed in conjunction with a limited investigation conducted at the Bretz Mine for DEQ also located in Malheur County, Oregon. Results of the Bretz Mine investigation are presented under separate cover. This document was prepared under Task Order No. 71-03-10.

Previous investigations at the site indicated that heavy metals contamination was detected in the site surface soil and in sediment samples collected from nearby drainage pathways. It was concluded that the surface water pathway was the only significant migration pathway from the site (Weston 2002); however, the extent of sediment, surface water, fish tissue, soil, and road material contamination had not been delineated.

This report describes the additional sediment, surface water, fish tissue, soil, and road material sampling at the Opalite Mine site, and describes how the objectives of the SI were met.

1.1 Purpose and Objectives

This SI expanded upon the results of limited investigations conducted by DEQ (DEQ 2001a) and Weston Solutions, Inc. (Weston) under contract to the United States Environmental Protection Agency (EPA; Weston 2002). The purpose of the SI is to provide additional data to support the evaluation of potential threats to human health and the environment from historic mercury mining at the site.

Specific SI objectives included the following tasks:

- Characterize the nature and extent of contamination in affected media;
- Evaluate contaminant transport and migration pathways to affected media;
- Evaluate contaminant exposure pathways to human and ecological receptors;

- Assess risk to human health and ecological receptors; and
- Assess the need for interim removal action measures.

1.2 Scope of Work

The investigation mainly focused on presence of heavy metals at the Opalite Mine site, and potential off-site migration of metals. In addition, samples were collected and analyzed using a variety of non-routine analytical techniques to assist with the evaluation of acid-generating potential and leachability of source materials, and speciation of mercury and arsenic. Such information was collected to facilitate a better understanding of fate and transport, as well as toxicity, of site contaminants.

Limited investigation activities were also conducted at the Bretz Mine, an abandoned mercury mine located approximately 5 miles east of the Opalite Mine. Results of this limited investigation are provided under separate cover. Selected results of the Bretz Mine investigation are presented in this report in order to assist with the evaluation of area-wide impacts of the two abandoned mines.

1.3 Report Organization

This report presents background information, including a site description and brief summary of previous investigations (Section 2); a discussion of field activities (Section 3); a discussion of SI results (Section 4); an assessment of risk to human health and ecological receptors (Section 5); a time-critical removal action assessment (Section 6); a removal assessment (Section 7); a summary and recommendations (Section 8); and a list of references used to prepare the report (Section 9).

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Background Summary

2.1 Site Location and Description

The Opalite Mine is an inactive mercury mine located on patented mining claims in the extreme southern end of Malheur County Oregon, approximately 15 miles northwest of McDermitt, Nevada (Figure 1). The mine is surrounded by public land administered by the Vale District of the Bureau of Land Management.

The site is approximately 342 acres in size. The elevation of the site is between approximately 5,200 and 5,400 feet above sea level. The climate of the area is arid, and the sparse vegetation consists of grasses, sagebrush and other shrubs. Willows and other woody vegetation are present along many of the local creeks. Mine Creek flows toward the south along the west side of the site. An unnamed tributary of Cowboy Creek flows toward the southeast along the east side of the site. (DEQ 2001a)

The Opalite Mine was developed using the glory hole method, in which tunnels were driven horizontally beneath the ore body, and raises and inclines were driven upward to the surface to remove the near-surface ore deposit from the glory hole. The Opalite Mine workings include a glory hole (referred to in previous investigations as the mine pit), two tunnels (Tunnel No. 1 and Tunnel No. 2), two large trenches located northeast of the glory hole (northeast trench and southwest trench), numerous shafts, raises, winzes, and inclines/declines, and numerous smaller exploratory prospects and excavations. Other mine features include overburden and waste rock piles, remains of processing facilities, and two large piles of burned ore. Key features of the Opalite Mine are illustrated in Figures 2 and 3.

The Bretz Mine, located approximately five miles east of the Opalite Mine, is described in the *Opalite Mine Site Investigation Work Plan* (E & E 2003).

2.2 Site History

The Opalite mercury deposit was discovered by William Bretz in 1924. In April 1925, F.W. Bradley formed the Mercury Mining Syndicate and began development of the Opalite Mine. Ore processing facilities were constructed in 1926 (Schuette 1938).

2. Background Summary

The Opalite Mine was developed using the glory hole method. Tunnels (Nos. 1 and 2) were driven beneath the ore body approximately 100 feet beneath the level of the ore outcrops, and raises were driven upward to the surface. Ore from the glory hole (also referred to as the surface pit) and various sublevels was drawn down through the raises and shafts to haulageways, and trammed via the tunnels to an ore stockpile near the ore processing facilities (Brooks 1963).

In general, processing of mercury ore is a relatively straightforward process, usually involving roasting of the ore to volatilize the mercury and collecting the mercury in a condensing system. At some mines, beneficiation of ore prior to roasting has been practiced. For example, at the Bretz Mine, a flotation mill was reportedly constructed in 1956 to concentrate the ore minerals prior to shipment to the ore processing facility at the Opalite Mine. (Brooks 1963)

In general, roasting of mercury ore is done in either furnaces or retorts. Furnaces are typically used where relatively large quantities of ore are available. A furnace was constructed at the Opalite Mine in 1926 to process the ore recovered from the Opalite Mine, as well as ore concentrates transported by truck from the nearby Bretz Mine. The furnace was 5 feet in diameter and 70 feet long, and could process 80 to 100 tons of ore per day (Brooks 1963).

Rotary furnaces such as the one formerly used at the Opalite Mine consist of a tubular steel shell lined with firebrick or other refractory material mounted on a slope of between approximately 4% and 13%. Ore is fed continuously into the upper end of the furnace, which is heated by an oil burner at the lower end of the furnace. As the furnace rotates, ore moves downward to the lower end and is discharged. The mercury is vaporized from the ore as the ore moves downward toward the lower end of the furnace. The mercury vapor, along with combustion gases and dust, is drawn from the upper end of the furnace by a fan. A condensing system, consisting of a dust collector, condenser pipes, and suction fan, is located at the upper end of the furnace to condense and collect the mercury vaporized from the ore. The mercury is condensed and collected in a series of vertical pipes joined at the top and bottom alternately with U-shaped connections. (Brooks 1963)

Retorts are generally small and inexpensive to install, but due to comparatively higher fuel and labor costs, are usually employed at small mines with high-grade ore, or at mines in the early stages of development. Four retorts were used to process ore at the Bretz Mine, presumably during the early assessment period.

The Opalite Mine produced a total of 12,367 flasks of mercury (a flask is equivalent to 76 pounds) between 1927 and 1961, with the vast majority of the production occurring before 1943. Only spotty production was recorded between 1944 and 1961 (Brooks 1971). Current Malheur County Tax records indicate that Bradley Mining Company of San Francisco, California, owns the site (DEQ 2001a).

The history of the Bretz Mine is summarized in the *Opalite Mine Site Investigation Work Plan* (E & E 2003).

2.3 Previous Investigations

Previous investigations at the Opalite Mine include a PA conducted in June 2000 by DEQ (2001a), and a SI conducted by Weston (2002) for the EPA.

The following potential contaminant source areas at the Opalite Mine were identified by DEQ (2001a) and verified by Weston (2002):

- **Open Pit.** A large open pit (referred to in this report as the glory hole) is present in the northeast portion of the site. This area contains in situ mineralized material that may be a source of mercury and other heavy metals contamination and possible acid mine drainage (AMD) and acid rock drainage (ARD). There are no surface water run-on/off controls in the pit area.
- **Underground Mine Workings.** Mine tunnels and shafts were identified as potential sources of AMD/ARD, although no evidence of water drainage has been observed during the site visits.
- **Waste Rock.** Waste rock piles associated with the mine workings, including the #1 Adit (referred to in this report as Tunnel No. 1), were identified as potential sources of ARD and metals contamination.
- **Former Ore Processing Facility.** The remains of a former ore processing facility, that formerly included a large rotary furnace, are located in the central portion of the site. This area was identified as likely to contain high concentrations of mercury.
- **Burned Ore Piles.** Two large burned ore piles are located on either side of the processing facilities.

DEQ (2001a) identified stream sediment downstream of the site as an area of concern. Mine Creek was observed to be flowing, and small fish were present.

Samples were collected from the potential sources identified above and from various target locations during the PA and/or SI. Analytical results are presented in tables provided in the *Opalite Mine Site Investigation Work Plan* (E & E 2003), and are briefly discussed below.

As part of the PA, DEQ (2001a) collected four samples for total mercury analysis. Total mercury results for surface soil samples were 51 milligrams per kilogram (mg/kg) from the open mine pit, 478 mg/kg from the waste rock pile at the portal of Tunnel No. 1, and 21.8 mg/kg from one of the burned ore piles. Total mercury

2. Background Summary

in a sediment sample collected at Mine Creek was 110 mg/kg. DEQ concluded that the surface water pathway at the site is very significant, with high potential for mercury to impact sensitive receptors such as the Lahontan Cutthroat Trout, a federally listed threatened species. The soil (direct contact) and air (inhalation of dust and mercury vapor) pathways were also concluded to be significant at the site, although exposure risk was concluded to be limited by the small number of human receptors and the limited amount of time they would be expected to be present at the site. A SI or remedial investigation (RI) was recommended.

As part of the SI for the EPA, Weston (2002) collected surface soil, burned ore material, and sediment samples for analysis for Target Analyte List (TAL) metals. Surface soil samples were collected from a background location (BK001) and each of the following source areas: the two burned ore piles (MS001 through MS004), the former ore processing facility (MS005 through MS008), the glory hole (MS009), and the waste rock pile at Tunnel No. 1 (MS010). Arsenic and total mercury were detected at concentrations significantly higher than background in all of the source samples. Arsenic was detected in source samples at concentrations ranging from 17.6 mg/kg (MS007) to 1,060 mg/kg (MS002). Total mercury was detected in source samples at concentrations ranging from 14.8 mg/kg (MS003) to 792 mg/kg (MS009). Selenium was detected at concentrations significantly higher than background in three of the four samples collected from the burned ore piles (1.7 mg/kg to 2.3 mg/kg, MS002, MS003, and MS004), the former ore processing facility (1.8 mg/kg, MS008), and the glory hole (1.3 mg/kg, MS009). Barium (3,210 mg/kg, MS005) and nickel (229 mg/kg, MS008) were significantly higher than background in samples collected at the former ore processing facility.

Weston (2002) collected background and target sediment samples at McDermitt Creek (ST001, ST002, and ST003) and Mine Creek (ST004 through ST008). Arsenic and total mercury were detected at concentrations significantly higher than background. Arsenic concentrations ranged from 5.8 mg/kg (ST004) to 29.8 mg/kg (ST007). Total mercury concentrations ranged from 0.62 mg/kg (ST007) to 4.3 mg/kg (ST007). In addition, beryllium was detected in ST007 at a concentration (2.0 mg/kg) significantly higher than background. Mercury was not detected in sediments collected at McDermitt Creek. None of the constituents detected in the sample from McDermitt Creek were reported at concentrations significantly higher than background.

Weston (2002) concluded that the surface water pathway was the only significant migration pathway at the site. The groundwater and air migration pathways and the soil exposure pathway were not evaluated because they were not expected to be significant at the site.

Results of previous investigations at the Bretz Mine are summarized in the *Opalite Mine Site Investigation Work Plan* (E & E 2003).

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Field Investigation Activities

As discussed above, previous investigations have documented metals contamination in on-site sources and sediments collected near the site. The current SI involved further characterization of site sources and evaluation of potential migration and impacts from such sources. SI field activities were completed over two phases. SI sampling activities were generally conducted in accordance with the *Opalite Mine Site Investigation Work Plan* (E & E 2003) unless otherwise noted.

Phase I field activities were completed during the week of December 15, 2003. Field activities focused on collection of surface samples at potential contaminant sources (in situ glory hole rock material, waste rock piles and dumps, burned ore piles, and ore processing area soils) and sediment from several nearby drainages. Other Phase I SI activities include completion of a DEQ Level I Scoping ecological risk assessment (ERA) site visit, characterization of numbers, types, and physical characteristic of mine openings, and completion of a preliminary bat survey.

Phase II field activities were completed during the week of June 7, 2004. Phase II activities included collection of additional source material samples, and surface water, sediment, and fish tissue samples from locations in nearby drainages upgradient and downgradient of site contaminant sources.

In conjunction with the Phase II field activities at the Opalite Mine, E & E performed limited investigation activities at the Bretz Mine. Investigation activities at the Bretz Mine included sampling of source materials (ore processing area soils, waste rock, and low-grade ore), and of surface water and sediment in the vicinity of the Bretz Mine. Results of the Bretz Mine investigation activities are summarized in the Bretz Mine Data Summary Report (E & E 2004). For the purpose of better understanding the impacts on streams from other sources in the area of the Opalite Mine, the results of the sediment and surface water samples collected as part of the Bretz Mine investigation are also presented in this report. Assessment of risk to human health and ecological receptors is limited to the Opalite Mine, however.

3. Field Investigation Activities

During each phase of SI fieldwork, samples were field-screened. Selected samples were analyzed at fixed analytical laboratories for total metals analysis as well as several non-routine analytical procedures to evaluate acid-generating potential, leachability, and speciation of arsenic and mercury to provide information on potential fate and transport as well as toxicity of site contaminants. Fixed laboratory analyses were performed at Columbia Analytical Services, located in Kelso, Washington, and Brooks Rand LLC, located in Seattle, Washington.

E & E surveyed horizontal coordinates of most of the sample locations and other important site features using a Trimble Pro-XRS mapping grade Global Positioning System (GPS). These data were differentially corrected in real-time using location data from a base station. A limited number of sample locations were surveyed using a handheld Garmin eTrex Vista GPS. GPS location data were used to generate geo-referenced maps of sample locations and site features.

Details of the Opalite Mine SI field activities are summarized in the subsections below. Photographic documentation of site conditions is provided in Appendix A.

3.1 Source Sampling

3.1.1 Phase I

Surface soil/source material samples were collected from potential source areas including: the ore processing area (OP01 through OP37); the northern burned ore pile (NP01 through NP06); the southern burned ore pile (SP01 through SP06); waste rock piles associated with Tunnel No. 1 and Tunnel No. 2 (WR01 through WR11); a waste rock dump located east of the glory hole (DP01 through DP04); and in situ material from the glory hole (GH01 and GH02). No subsurface soil samples were collected because of frozen ground conditions.

The samples were field-screened for mercury using a Lumex RA-915+ mercury analyzer. Selected source material samples were submitted for analysis for one or more of the following analyses:

- TAL metals by EPA SW-846 Methods 6010, 6020, and 7471;
- Synthetic precipitate leaching procedure (SPLP) metals by EPA SW-846 Methods 1312, 6010, 6020, and 7471;
- Acid generating potential (AGP) by EPA Method 600;
- Methylmercury by EPA Method 1630; and
- Selective extraction mercury analysis.

Sample descriptions and identification of analyses are presented in Table 1. Sample locations are illustrated in Figures 4 and 5.

3.1.2 Phase II

During Phase II field activities, subsurface samples were collected from waste rock piles, the burned ore piles, and the ore processing area. Two subsurface samples of waste rock were collected, one from near Tunnel No. 1 (WR12), and the other near Tunnel No. 2 (WR11). Two subsurface soil samples were collected from the ore processing area (OP38 and OP39), and one subsurface sample was collected from each of the burned ore piles (NP07 and SP07). Each subsurface sample was collected from approximately 2 to 3 feet below ground surface using a decontaminated stainless steel hand auger.

The samples were field-screened for mercury using a Lumex RA-915+ mercury analyzer and for total metals using an Innov-X Systems X-ray fluorescence (XRF) analyzer. The waste rock and soil samples were also submitted to a fixed laboratory for one or more of the following analyses:

- TAL metals by EPA SW-846 Methods 6010, 6020, and 7471;
- SPLP metals by EPA SW-846 Methods 1312, 6010, 6020, and 7471; and
- AGP by EPA Method 600.

Sample descriptions and identification of analyses are presented in Table 2. Sample locations are illustrated in Figures 4 and 5.

3.1 Sediment Sampling**3.2.1 Phase I**

During Phase I field activities, sediment samples were collected from a location in Mine Creek upgradient of the Opalite Mine (MC02), and locations downgradient of Opalite Mine in Mine Creek (MC01), Cowboy Creek (CC01), Hot Creek (HC01), and McDermitt Creek (MT01). A sample was also collected from Indian Creek upstream of its confluence of McDermitt Creek (IC01).

Each sample was screened for total mercury with a Lumex mercury analyzer. In addition, one sample (CC01) was submitted to fixed laboratories for the following analytical parameters:

- TAL metals by United EPA SW-846 Methods 6010, 6020, and 7471;
- Arsenic (III) by EPA Method 1632;
- Methylmercury by EPA Method 1630; and
- Selective extraction mercury analysis.

Sample descriptions and identification of analyses are presented in Table 1. Sample locations are illustrated in Figure 6.

3.2.2 Phase II

During Phase II field activities, sediment samples were collected from locations in Mine Creek upgradient (MC01 and OPMW01) and downgradient (MC02) of Opalite Mine; Cowboy Creek upgradient (OPCC02) and downgradient (OPCC01)

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of Opalite Mine; Hot Creek, downgradient of Opalite Mine (HC01); McDermitt Creek upgradient (MT01) and downgradient (MT02) of its confluence with Hot Creek; and Cottonwood Creek upgradient of its confluence with McDermitt Creek (CT01).

Several of the Phase II sediment samples were field-screened for mercury using a Lumex RA-915+ mercury analyzer and for total metals using an Innov-X Systems XRF analyzer. Other samples were not field-screened because they were collected late in the field event, and were planned for submission for fixed laboratory analysis. Sediment samples were submitted to a fixed laboratory analysis for one or more of the following analyses:

- TAL metals by EPA SW-846 Methods 6010, 6020, and 7471;
- Arsenic (III) by EPA Method 1632;
- Methylmercury by EPA Method 1630; and
- Selective extraction mercury analysis.

Sample descriptions and identification of analyses are presented in Table 2. Sample locations are illustrated in Figure 7.

3.2 Surface Water Sampling

During Phase II field activities, surface water samples were collected from locations on Mine Creek upgradient (MC01) and downgradient (MC02) of Opalite Mine; Hot Creek, downgradient of Opalite Mine (HC01); McDermitt Creek upgradient (MT01) and downgradient (MT02) of its confluence with Hot Creek; and Cottonwood Creek upgradient of its confluence with McDermitt Creek (CT01 and field duplicate CT04). Following collection of water samples, water quality parameters were measured directly in the stream at each of the sample locations. Each water sample was submitted to a fixed laboratory for the following analyses:

- TAL metals by EPA SW-846 Methods 6010, 6020, and 7471;
- Hardness by EPA Method 130.1;
- Low-level mercury by EPA Method 1631;
- Low-level arsenic by EPA Method 1632; and
- Methylmercury by EPA Method 1630.

Sample descriptions and identification of analyses are presented in Table 2. Sample locations are illustrated in Figure 7.

3.3 Fish Tissue Sampling

In coordination with the Phase II field activities, DEQ and Oregon Department of Fish and Wildlife (ODFW) personnel collected fish tissue, benthic macroinvertebrate, and water samples as part of a stream habitat monitoring

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program. The fish samples were collected using electrofishing techniques, at locations collocated with the Phase II SI surface water samples (MC01, MC02, HC01, MT01, MT02, and CT01). Following species identification and physical description, the whole fish samples were placed in ziplock plastic bags and placed in an iced cooler under chain-of-custody. Custody of the fish was transferred from DEQ/ODFW to the E & E field sampling team, which submitted the samples to Columbia Analytical Services. Columbia Analytical Services homogenized the whole body samples, and divided them into aliquots. Columbia Analytical Services analyzed one set of aliquots for selected metals (by EPA SW-846 Methods 6010, 6020, and 7471), and shipped the second set of frozen aliquots to Brooks Rand LLC under chain-of-custody. Brooks Rand LLC analyzed the second set of aliquots for low-level mercury by EPA Method 1631, and arsenic (III) by EPA Method 1632. Sample descriptions and identification of analyses are presented in Table 2. Sample locations are illustrated in Figure 7.

3.4 Road Material Sampling

During Phase II field activities, samples of roadbed material were collected from twenty locations (RD01 through RD20) along the gravel and dirt roads in the vicinity of the Opalite Mine. The samples were collected at the direction of the DEQ Project Manager to evaluate the presence of site-related contaminants in the road bed materials, which reportedly locally include calcine material obtained from the Opalite Mine burned ore piles. Samples were collected by the DEQ project manager and the E & E field sampling team at intervals of approximately 0.5 to 1 mile. Samples were collected from the upper two to three inches of the road bed with a dedicated plastic scoop, placed into a Ziplock® bag, and placed into iced coolers under chain-of-custody. Each sample was field-screened for mercury using a Lumex RA-915+ mercury analyzer, and for total metals using an Innov-X Systems XRF analyzer.

Sample descriptions and identification of analyses are presented in Table 2. Sample locations are illustrated in Figure 8.

3.5 Field Screening

Samples were field screened for mercury and total metals as described below.

3.5.1 Phase I

Soil and sediment samples were analyzed for total mercury using a Lumex RA-915+ Mercury Analyzer (Lumex) equipped with a soil analysis attachment. The Lumex rental unit was not equipped with the appropriate database software when shipped to the E & E field team; therefore, it was not possible to use the Lumex in the field as planned. However, upon demobilization from the field, the E & E site chemist performed analysis of most of the samples, and the screening results were used to aid the selection of samples submitted for fixed laboratory analysis. Neither of the samples of in situ ore material from the glory hole was analyzed with the Lumex because the sample material, consisting of chalcedony fragments hammered from the outcrop, was too coarse to analyze. It was not possible to

3. Field Investigation Activities

analyze several of the surface soil samples due to a malfunction of the soil attachment component of the Lumex.

3.5.2 Phase II

During Phase II field activities, samples were field-screened for mercury using a Lumex equipped with a soil analysis attachment, and for total metals using an Innov-X Systems XRF analyzer. Field screening was performed by an E & E chemist both on-site and at the field team base hotel in McDermitt, Nevada. The Lumex air-flow rate malfunctioned occasionally during analyses, reducing the mercury vapors that flowed past the detector. This factor likely contributed to low-biased results, as discussed in Section 4.

At each surface water sample location, immediately following collection of water samples, stream water was field-analyzed for water quality parameters. Temperature, dissolved oxygen, specific conductance, pH, and turbidity, were measured directly in the stream using a calibrated Horiba U-70 water quality meter.

3.6 DEQ Level I Scoping Ecological Risk Assessment Site Visit

In order to identify ecological receptors and exposure pathways, E & E conducted a Level I Scoping ERA in accordance with DEQ (2001b) guidance. Completion of the Level I Scoping ERA included a site visit by an E & E biologist during Phase I field activities to obtain photographic documentation and complete the Ecological Scoping Checklist and Evaluation of Receptor-Pathway Interactions. Prior to Phase I field activities, E & E contacted applicable agencies to determine the presence threatened, endangered, and sensitive species and their habitat. Results of the Level I Scoping ERA were incorporated into a Level II Screening ERA as part of the SI (Section 5).

3.7 Mine Opening Characterization and Preliminary Bat Survey

As part of the assessment of interim removal action measures, E & E characterized physical hazards at the site, including highwalls and mine openings. Each mine opening was identified and characterized to provide information on possible closure approaches. In addition, a preliminary bat survey was conducted to evaluate the possibility that bats and/or bat habitat exist within the underground workings at the Opalite Mine.

4

Site Investigation Results

This section summarizes the results of the SI sampling and other activities.

4.1 Quality Assurance Review

An E & E chemist performed a quality assurance (QA) review of all laboratory analytical data for samples submitted to fixed laboratory analyses. Copies of QA memoranda are included in Appendix B.

4.2 Evaluation of Field-Screening Data

In order to evaluate their usefulness, the field-screening results were compared to fixed laboratory analytical results for soil, sediment, waste rock, and suspected low-grade ore samples collected during each phase of the SI. Results of the comparison are discussed below.

4.2.1 X-Ray Fluorescence

XRF field-screening results were compared to fixed laboratory total metals results for selected analytes (antimony, arsenic, chromium, copper, lead, manganese, mercury, selenium, and zinc). A total of seventeen samples collected during the Phase II field activities, including samples collected at the Bretz Mine, were both XRF field-screened and analyzed by the fixed laboratory for TAL metals. In order to compare XRF results (determined on a wet weight basis) with the fixed laboratory results (reported on a dry weight basis), the raw XRF results were corrected for moisture content. The corrections were made by dividing the XRF result by the percent solids result reported by the fixed laboratory for the laboratory aliquot. It was assumed that the XRF aliquots had the same moisture content as the laboratory aliquots.

In general, the XRF-screening results compare well with the associated fixed laboratory results, with correlation coefficients greater than 0.700 (which is the lower limit considered by EPA to be acceptable for field screening) for each of the selected analytes except copper (0.523), lead (0.166), and zinc (0.647). Excluding one outlying point for zinc results in a correlation coefficient of 0.902. There were a significant number of chromium and selenium XRF results that were below the XRF detection limit; these results agreed with the corresponding fixed laboratory results but were not used in the correlation calculations; therefore

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correlation coefficients were not calculated for these analytes. The correlation coefficient for mercury was 1.000. These results demonstrate that XRF field screening yielded satisfactory field-screening results for antimony, arsenic, chromium, manganese, mercury, selenium, and zinc for the Phase II sampling activities. Correlation plots of XRF-screening results versus fixed laboratory results for total mercury and total arsenic are provided in Appendix C.

Because moisture data are not available for all of the samples screened with the XRF, it was not possible to moisture-correct all XRF results. Therefore, all XRF results are presented in the attached summary tables on a wet-weight basis (non-corrected), and are understood to be biased low. All XRF results are assigned an “F” (field screening) qualifier.

4.2.2 Lumex Mercury Analyzer

A comparison of Lumex mercury screening and fixed laboratory total mercury (TAL metals) analytical results is presented below.

Phase I

During Phase I, seventeen samples were both Lumex mercury-screened and analyzed at a fixed laboratory for total mercury. In order to compare Lumex results, (determined on a wet weight basis) with the fixed laboratory results (reported on a dry weight basis), the raw Lumex results were corrected for moisture content by dividing the Lumex mercury result by the percent solids result reported by the fixed laboratory for the laboratory aliquot. It was assumed that the Lumex aliquots had the same moisture content as the laboratory aliquots. Solid content values of the laboratory aliquots ranged from 62.8% to 93.9%. Therefore, the corresponding raw Lumex results were biased low by between approximately 6.1% and 37.2%. In general, the moisture-corrected screening results compare well with the associated fixed laboratory results, with a correlation coefficient of 0.82.

Because moisture data are not available for all of the samples screened with the Lumex, it was not possible to moisture-correct all Lumex results. Therefore, all Lumex results are presented in the attached summary tables on a wet-weight basis (non-corrected), and are understood to be biased low. All Lumex results are assigned an “F” (field screening) qualifier.

A correlation plot of Phase I Lumex field-screening results versus fixed laboratory results for total mercury is provided in Appendix C.

Phase II

During Phase II, a total of thirteen samples were both Lumex field-screened and analyzed by the fixed laboratory for total mercury. Two of the sediment samples contained greater than 80% moisture; results from these samples were excluded from the comparison. The raw Lumex results were corrected for moisture content in the same manner as the Phase I Lumex samples. The Phase II Lumex

4. Site Investigation Results

screening results compared poorly with the associated fixed laboratory total mercury results, with a correlation coefficient of -0.019. The Lumex results are consistently, and significantly, lower than the associated fixed laboratory results. One potential contributing factor for this is that only one of the eleven Lumex results was within the calibration range (the Lumex results exceeded the calibration range and are considered low-biased). Another potential factor is that the Lumex air-flow rate malfunctioned occasionally during analysis, reducing the mercury vapors that flowed past the detector, likely contributing to low-biased results.

Because moisture data are not available for all of the samples screened with the Lumex, it was not possible to moisture-correct all Lumex results. Therefore, all Lumex results are presented in the attached summary tables on a wet-weight basis (non-corrected). The Lumex results that exceeded the calibration range are presented in italics in the applicable tables. These results are believed to be biased low. All Lumex results are assigned an “F” (field screening) qualifier.

A correlation plot of Phase II Lumex field-screening results versus fixed laboratory results for total mercury is provided in Appendix C.

4.3 Field Screening and Fixed Laboratory Results

Field screening and fixed laboratory analytical results for samples collected during Phase I and Phase II SI field activities are summarized below. Results are detailed in Tables 3 through 15. In order to facilitate comparison of SI data with available background concentration data, results of applicable background samples collected during the Weston (2002) SI are included in the tables.

4.3.1 Total Metals

Source material, sediment, surface water, and fish tissue samples were submitted for fixed laboratory analysis for TAL metals to determine total metals content. In addition, total metals concentrations were evaluated using field-screening techniques. Low-level analysis for arsenic and mercury in surface water, sediment, and fish tissue samples also was performed in order to evaluate concentrations relative to DEQ Level II ecological screening level values (SLVs).

Total metals results are presented below, organized by sampling area and medium. Total metals results are summarized in Tables 3 through 15. Results were compared to EPA Region 9 preliminary remediation goals (PRGs) and to DEQ Level II SLVs. Results that exceeded one or more of the values are presented in the tables in reverse font. Specific total metals results and their significance are discussed in Section 5.

Glory Hole

During Phase I field activities, two samples of in situ rock material (chalcedony) were collected from the glory hole. Both samples were analyzed for TAL metals. Total metals results are presented in Table 3.

Waste Rock

During Phase I field activities, eight surface samples of waste rock associated with Tunnel No. 1 and Tunnel No. 2 were analyzed for total mercury with the Lumex. Two of the samples (locations WR01 and WR05) were also analyzed for TAL metals. Total metals results are presented in Table 4.

During Phase II field activities, two subsurface samples were collected from waste rock piles associated with Tunnel No. 1 and Tunnel No. 2. Each sample was field-screened for mercury and metals, and submitted to a fixed laboratory for TAL metals. Total metals results are presented in Table 5.

Ore Processing Area Soils

During Phase I field activities, surface soil samples from the ore processing area were analyzed for total mercury with the Lumex, and samples from four locations (OP06, OP18, OP33, and OP35) were also analyzed for TAL metals. Results are summarized in Table 6. Lumex mercury screening results for the ore processing area soils are generally significantly less than the corresponding fixed laboratory total mercury results.

During Phase II field activities, two subsurface soil samples were collected from the ore processing area and analyzed for TAL metals. Sample results are presented in Table 7.

Waste Dump

During Phase I field activities, four samples of surface soil (locations DP01, DP02, DP03, and DP04) were collected from the waste rock dump located east of the glory hole. All four samples were field-screened for mercury with the Lumex and analyzed for TAL metals. Results are presented in Table 8.

Burned Ore Piles

During Phase I field activities, five surface soil samples from the northern burned ore pile and six surface soil samples from the southern burned ore pile were field-screened for mercury with the Lumex. Of these, three samples from the pile (NP01, NP03, and NP04) and three samples from the southern pile (SP01, SP03, and SP05) were also analyzed for TAL metals. Results are presented in Table 9.

During Phase II field activities, one subsurface sample was collected from each burned ore pile. Samples were field-screened using the Lumex and XRF, and analyzed for TAL metals. Results are presented in Table 10.

Surface Water

During Phase II field activities, surface water samples were collected at a total of seven locations, including one location near the Bretz Mine. Total metals results, including low level mercury and low level arsenic analytical results, are presented in Table 11.

4. Site Investigation Results

Sediment

During Phase I field activities, six sediment samples were analyzed for total mercury with the Lumex, and the sample from Cowboy Creek (CC01) was also analyzed for TAL metals. Results are presented in Table 12.

During Phase II field activities, sediment samples were collected from locations in the vicinity of the Opalite Mine as well as the Bretz Mine. Some samples were field-screened using the Lumex and XRF. Samples were submitted to a fixed laboratory for TAL metals analysis. Results are presented in Table 13.

Field screening and fixed laboratory total mercury concentration were evaluated by distance along streams for Mine Creek/Hot Creek, McDermitt Creek, and Little Cottonwood Creek/Cottonwood Creek. Results are presented graphically in Appendix D.

Fish Tissue

During Phase II field activities, fish samples were collected by DEQ and ODFW personnel. E & E submitted the samples to fixed analytical laboratories for analysis for selected total metals, including low level arsenic and low level mercury. Results are presented in Table 14.

Road Material Samples

During Phase II field activities, DEQ and E & E personnel collected samples of road bed material. Field-screening results are presented in Table 15.

4.3.2 Acid Generating Potential

In general, ore, low-grade ore, burned ore, and waste rock materials that are exposed to the environment can contribute metals and other contaminants to the environment by leaching. Such leaching may occur under pH-neutral conditions, but is accelerated under acidic conditions generated by oxidation of metallic sulfide minerals. Sulfide minerals such as cinnabar and pyrite are documented to exist in the ore materials at both the Opalite Mine and Bretz Mine. When pyrite and certain other sulfide minerals are exposed to moisture in oxidizing conditions, ARD/AMD may occur, and metals may be liberated. Acid generation contributes to further accelerated metals and AMD/ARD generation, which may impact surface water and groundwater at the sites. The acid generating ability of any given material involves a complex set of biologically controlled chemical reactions that depend on the mineral and chemical composition (including acid-generating and acid-neutralizing components), presence of reactive coatings on mineral surfaces, and site-specific environmental conditions (e.g., pH, oxygen fugacity, temperature, moisture, bacteria present). Nonetheless, the AGP of materials can be estimated by one of several tests such as EPA AGP.

In general, when no organic material containing sulfur is present in samples, potential for acid generation is attributed to the potential oxidation of sulfide

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minerals. The sulfide sulfur content is assumed to react stoichiometrically with oxygen and water to form sulfuric acid (H_2SO_4). The produced acid has an acid neutralization equivalence in calcium carbonate (CaCO_3). AGP is therefore expressed in tons of CaCO_3 per thousand tons of material (TCaCO_3/k).

Selected source material samples were evaluated for AGP during each phase of fieldwork, as discussed below.

Phase I

One surface sample of in situ material from the glory hole (GH01), two samples of waste rock associated with Tunnel No. 1 (WR01) and Tunnel No. 2 (WR05), one sample from the waste rock dump located east of the glory hole (DP03), one sample from the northern burned ore pile (NP03), and one sample from the southern burned ore pile (SP05) were analyzed at a fixed laboratory for AGP. The result for each of the samples was less than $0.3 \text{ TCaCO}_3/\text{k}$, indicating a low potential for the sampled materials to generate acid. Phase I AGP analytical results are presented in Tables 3, 4, 8, and 9.

Phase II

During Phase II, two subsurface samples of burned ore and one subsurface sample of waste rock were analyzed for AGP. As with the Phase I results for the surface samples of burned ore, the subsurface samples of burned ore from NP07 and SP07 exhibited low potential to generate acid (0.31 and less than $0.3 \text{ TCaCO}_3/\text{k}$, respectively). However, the result for the subsurface waste rock sample (WR11) was $4.38 \text{ TCaCO}_3/\text{k}$, indicating some potential to generate acid. Results are presented in Tables 5 and 10.

4.3.3 Synthetic Precipitate Leaching Procedure

The metal constituents that may be released by leaching can be identified by one of several leach tests. The EPA SPLP is widely regarded as the preferred technique for evaluating potential metals leaching of mine waste.

Selected source material samples were evaluated for SPLP metals during each phase of SI fieldwork to determine which metal constituents of the materials may be released into the environment as a result of leaching, as discussed below.

Phase I

One surface sample from the glory hole (GH01), two samples of waste rock associated with Tunnel No. 1 (WR01) and Tunnel No. 2 (WR05), one sample from the waste rock dump located east of the glory hole (DP03), one sample from the northern burned ore pile (NP03), and one sample from the southern burned ore pile (SP05) were analyzed at a fixed laboratory for SPLP metals.

Mercury was detected in the leachate from all samples. The highest mercury leachate concentration was for the glory hole sample (0.168 milligrams per liter [mg/L]), followed by the waste rock samples (0.054 mg/L and 0.077 mg/L).

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Mercury concentrations were comparatively low in the leachates from samples from the waste rock dump east of the glory hole (0.003 mg/L) and the burned ore piles (0.006 mg/L and 0.004 mg/L).

Arsenic and antimony were detected in the leachate from the southern burned ore pile at 0.05 mg/L and 0.3 mg/L, respectively. These analytes were not detected in any of the other samples. Vanadium was detected in the leachates from the glory hole sample (0.02 mg/L), the waste dump sample (0.03 mg/L), and the southern burned ore pile sample (0.01 mg/L). Zinc was detected only in the leachate from the glory hole sample (0.1 mg/L).

Other metals detected in all the leachate samples include barium (as high as 0.4 mg/L), calcium (up to 8.35 mg/L), iron (up to 1.47 mg/L), and magnesium (up to 1.47 mg/L). Sodium was detected in the leachates from all but the glory hole sample (up to 9.6 mg/L).

Analytical results are presented in Tables 3, 4, 8, and 9.

Phase II

During Phase II field activities, one subsurface sample of waste rock (WR11) and two subsurface samples from the burned ore piles (NP07 and SB07) were analyzed for SPLP metals.

Mercury was detected in the leachate from the waste rock sample and one of the burned ore samples (NP07) at concentrations of 0.005 and 0.02 mg/L, respectively. Arsenic and antimony were detected in the leachates from the burned ore piles at concentrations as high as 1.8 and 0.68 mg/L, respectively. Vanadium was detected in the leachate from burned ore sample (NP07) at a concentration of 0.03 mg/L.

Other metals detected in one or more of the leachate samples include aluminum (up to 0.52 mg/L), calcium (up to 119 mg/L), iron (up to 0.62 mg/L), magnesium (up to 8.02 mg/L), manganese (up to 0.106 mg/L), potassium (up to 15.4 mg/L), and sodium (up to 4.6 mg/L).

Results are presented Tables 5 and 10.

4.3.4 Methylmercury

In general, the potential environmental impacts of mercury from mercury mine waste depend on the mercury species as well as the total mercury concentrations present in the source materials and impacted areas. The mercury species of greatest environmental concern is methylmercury, which is the most bioavailable form of mercury, and which can become concentrated through bioaccumulation in fish and fish-consuming biota.

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Formation of methylmercury in aqueous environments is enhanced by sulfate (SO_4^{2-}) and high concentrations of dissolved organic carbon in the presence of sulfate-reducing bacteria. Sulfate typically occurs at high concentrations in AMD as a result of oxidation of sulfide minerals. Although methylation can occur in mine site sources and in mine drainage, the process occurs predominantly in wetlands and larger aquatic bodies downstream of the mine sources. (Rytuba 2002)

Selected surface soil, sediment, and surface water samples were submitted for analysis of methylmercury by EPA Method 1630 to evaluate the bioavailability of mercury and to compare to DEQ Level II SLVs and EPA Region 9 PRGs. Greater than 95% of the mercury present in fish tissue is reported to be methylmercury (Bloom 1992); therefore, analysis of fish tissue for methylmercury was not performed.

Selected samples of source materials, sediment, and surface water were analyzed for methylmercury, as discussed below.

Phase I

Source surface samples from the glory hole (GH01), ore processing area (OP18), waste rock dump (DP03), waste rock piles (WR01 and WR05), and burned ore piles (NP03 and SP05), and a downgradient sediment sample (CC01), were analyzed for methylmercury. Methylmercury was detected at very low concentrations in source samples (between 0.000126 mg/kg and 0.0209 mg/kg) and in the downstream sediment sample (0.000884 mg/kg). These concentrations represent a small fraction of the total mercury for each medium. Results are presented in Tables 3, 4, 6, 8, 9, and 12.

Phase II

During Phase II SI field activities, selected sediment samples (CT01, MT02, HC01, and MC02), and surface water samples (CT01/CT04, MT01, MT02, HC01, MC01, MC02) were analyzed for methylmercury. Methylmercury was detected at low concentrations ranging from 0.000185 mg/kg to 0.0209 mg/kg in sediment (Table 13). In surface water, methylmercury was detected at low concentrations ranging from 0.00013 mg/L (CT01) to 0.00162 mg/L (MC02), and comprised less than approximately 9% of the total mercury content (Table 11).

4.3.5 Mercury Sequential Selective Extraction

As discussed above, methylmercury is the most bioavailable form of mercury. Methylation of mercury and its uptake is a complicated process governed by several variables. Mercury speciation plays a large role in determining how much of the mercury released from mine sources may become available for methylation in downstream aquatic environments. For example, elemental mercury and ionic mercury are more readily methylated than other forms of mercury. Speciation also dictates how much mercury is bioavailable for the direct ingestion exposure pathway, as well as influencing the mobility of mercury in the environment.

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Extended X-ray adsorption fine structure spectroscopy studies of mercury mine wastes indicate that the mercury species metacinnabar (m-HgS), corderoite ($\text{Hg}_3\text{S}_2\text{Cl}_2$), schuetteite ($\text{HgSO}_4\cdot\text{H}_2\text{O}$), and mercury chlorides are likely to form during the roasting of mercury ores, and each of these species is more soluble than cinnabar. (Rytuba 2002)

General information on mercury species in ore materials in the Opalite Mine area is available. For instance, according to Brooks (1963), the primary mercury ore mineral present within the Opalite Mining District, which includes both the Opalite Mine and the Bretz Mine, is cinnabar (HgS). Other mercury ore minerals documented in the Opalite Mining District, and which may be present at the Opalite Mine or Bretz Mine specifically, include metacinnabar, terlinguaite (Hg_2ClO), and native mercury. Rytuba (2002) states that the mercury chloro-sulfide mineral corderoite is the dominant ore mineral at the McDermitt area, Nevada, which includes the Opalite District. Other mercury-bearing minerals identified in the Opalite Mining District are Kenhsuite ($\text{Hg}_3\text{S}_2\text{Cl}_2$), Kleinite ($\text{Hg}_6\text{Cl}_3\text{N}_3\text{S}_{0.5} - \text{H}_2\text{O}$), and Radtkeite ($\text{Hg}_3\text{S}_2\text{ClI}$; Mindat.org 2003).

Specific information on the relative abundances of the ore minerals at the Opalite Mine and Bretz Mine is not available. Furthermore, mercury species information is lacking for the non-ore sources (e.g., burned ore, waste rock, and soils in the ore processing area) and sediments downstream of the mine.

A sequential selective extraction technique (Bloom et al. 2003) was employed to approximate relative proportions of water soluble, stomach acid (weak acid) soluble, organo-chelated, elemental, and sulfide bound forms of mercury in the Opalite Mine source and sediment samples. Although this technique does not identify exact mineral or oxidation state, it does differentiate between and quantify groups of mercury species based upon solubility. Each sequential extraction step dissolves a less soluble fraction.

A summary of the selective extraction technique and typical species identified by each extraction step is provided below.

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Extraction Step	Extractant	Fraction Description	Typical Species
1	De-ionized Water	Water soluble	HgCl ₂ , HgSO ₄ (salts)
2	pH 2 HCl/HOAc	Stomach acid soluble (weak acid)	HgO
3	1M KOH	Organo-chelated	CH ₃ Hg, Hg-humics, Hg ₂ Cl ₂
4	12 M HNO ₃	Elemental mercury	Hg ⁰ , Hg ₂ Cl ₂
5	Aqua Regia (concentrated HCl and HNO ₃)	Mercuric sulfide	HgS, m-HgS, HgSe, HgAu

Key:

CH₃Hg = Methylmercury
 HCl = Hydrochloric acid
 Hg = Mercury
 Hg⁰ = Elemental mercury
 HgAu = Mercury-gold amalgam
 HgCl₂ = Mercuric chloride
 Hg₂Cl₂ = Mercurous chloride
 HgO = Mercuric oxide
 HgS = Cinnabar
 HgSe = Mercuric selenide
 HgSO₄ = Mercuric sulfate
 HNO₃ = Nitric acid
 HOAc = Acetic Acid
 KOH = Potassium hydroxide
 m-HgS = Metacinnabar

Selected source material (including ore, low-grade ore, burned ore, and waste rock), surface soil, and sediment samples were analyzed for selective extraction mercury analysis. Results are presented below.

Phase I

Surface samples of source materials from the glory hole (GH01), ore processing area (OP18), waste rock dump (DP03), waste rock piles (WR01 and WR05), and burned ore piles (NP03 and SP05), and a downgradient sediment sample (CC01), were analyzed for mercury sequential selective extraction. Results indicate that between approximately 86.9% and 99.9% of the total mercury in the source samples and the Cowboy Creek sediment sample can be characterized as 'elemental' or 'sulfide' fractions. Comparatively low proportions (between 0.1% and 13.1%) of the total mercury exist in the comparatively soluble water soluble, stomach acid extractable, and organo-chelated forms. Results are presented in Tables 3, 4, 6, 8, 9, and 12.

Phase II

During Phase II field activities, selected sediment samples (CT01, MT02, HC01, and MC02) were analyzed for mercury sequential selective extraction. In sediment samples from MC02 and CT01, most of the mercury (75% and 88%, respectively) was in the sulfide mineral bound form, with organo-chelated and

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‘elemental’ forms comprising most of the rest of the mercury. For the samples from MT02 and HC01, most of the mercury (60% and 63%, respectively) was in the comparatively soluble organo-chelated form, with less soluble ‘elemental’ and sulfide bound forms comprising most of the rest of the mercury. Results are presented in Table 13.

4.3.6 Arsenic (III) Analysis

Arsenic typically exists in the environment in two valence states: arsenic (III), or arsenite; and arsenic (V), or arsenate. Toxicity of arsenic compounds vary based on valence state, form (inorganic or organic), physical state (gas, solution, or powder) and factors such as solubility, particle size, rates of absorption and elimination, and presence of impurities. Inorganic arsenic, usually in arsenic (III) form, is generally more toxic than organic arsenic. However, animal studies have shown that methyl and phenyl arsenates can produce health effects similar to those produced by inorganic arsenic. The toxicity of arsenic (III) is several times greater than that of arsenic (V) due to greater cellular uptake. However, at equivalent intracellular levels, arsenic (III) and arsenic (V) compounds are equally toxic. (ATSDR 2004)

Fish tissue samples were analyzed for arsenic (III) to evaluate fish consumption exposure for human and ecological receptors. Ecological SLVs for arsenic in sediment are in terms of arsenic (III); therefore, sediment samples also were submitted for arsenic speciation analysis. Results are presented below.

Phase I

One sediment sample collected from Cowboy Creek (CC01) was analyzed for arsenic (III) by EPA Method 1632. Arsenic (III) was detected in the sample from CC01 at a concentration of 0.302 mg/kg, which comprised a small fraction of the total arsenic in this sample (34.7 mg/kg). Results are presented in Table 12.

Phase II

During Phase II field activities, selected sediment samples (CT01, MT02, HC01, and MC02), and six fish tissue samples were analyzed for arsenic speciation.

Arsenic (III) was detected in sediment samples at concentrations ranging from 0.13 to 0.43 mg/kg, which represented a small proportion of the total arsenic concentrations, which ranged from 5.6 (estimated) to 28.8 (estimated) mg/kg. Results are presented in Table 13.

Arsenic (III) was detected in fish tissue at concentrations ranging from 0.036 mg/kg (MC01) to 0.198 mg/kg (CT01). Arsenic (III) comprised between 26% and 41% of the total arsenic detected in the fish tissue samples. Results are presented in Table 14.

4.3.7 Hardness

Surface water samples were analyzed for hardness to evaluate certain COPCs whose bioavailability decreases with increases in hardness. Although DEQ Level II SLVs do not account for hardness dependence of these COPCs, hardness data may be useful to evaluate risk in surface waters at the site. Results are presented in Table 11.

4.3.8 Water Quality Parameters

During Phase II field activities, water quality parameters were measured with a calibrated Horiba U-70 water quality meter at each surface water sample location. Results are summarized in Table 11. Notable water quality measurement results include the specific conductance and pH results at location BRCC01, located in a tributary to Cottonwood Creek downgradient of the west area workings at the Bretz Mine. The measured values, in conjunction with the comparatively high metals concentrations in the associated surface water sample, indicate AMD/ARD conditions.

4.4 DEQ Level I Scoping Level Ecological Risk Assessment Site Visit

The Level I Scoping Ecological Risk Assessment included completion of an Ecological Scoping Checklist and an Evaluation of Receptor-Pathway Interactions. Results of the DEQ Level I Scoping ERA are provided in Appendix E.

4.5 Mine Opening Characterization and Preliminary Bat Survey

Abandoned mines may serve as critical sites for bats to rear young in the summer, for hibernating in the winter, and for temporary havens and migratory rest stops during the spring and fall. In order to provide information on whether the workings of the Opalite Mine may provide such habitat, E & E conducted a preliminary bat survey between December 16 and December 18, 2003. E & E also obtained information from the Oregon Natural Heritage Information Center (ORNHIC). The purpose of the preliminary bat survey was to describe the mine openings, and document potential evidence of bat presence at each mine opening. The survey did not include underground entry. Locations of mine openings are illustrated in Figure 9.

In general, in order to determine if bats may be using a mine for hibernation, roosting, or rearing young several factors need to be evaluated to determine if potential bat habitat is present. Temperature, airflow, mine ventilation, predation, and proximity to food and water are the main factors in determining potential bat occupancy of a mine.

Larger bat colonies can sometimes raise young in mines with ambient temperatures as low as 56 degrees Fahrenheit (°F), but typically prefer temperatures of 66°F or higher (Tuttle and Taylor 1998). Bats that roost in

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smaller colonies require temperatures between 70°F and 90°F to raise young. Suitable winter roosting/hibernation habitat for most bat species requires temperatures between 40°F and 50°F during the winter months to protect bats from freezing.

Airflow within mines depends upon seasonal temperature changes and the mine configuration. Based on a review of historic mine maps and cross-sections (Schuette 1938 and Brooks 1963) and observations made during the SI, the principal openings at the Opalite Mine are Tunnel No. 1, Tunnel No. 2, and numerous shafts, raises, overhead stopes, winzes, and inclines/declines. Tunnels No. 1 and Tunnel No. 2 were driven beneath the ore body approximately 100 feet beneath the level of the ore outcrops, and raises and inclines were driven upward to the surface in the area of the glory hole. More mine openings were identified during the SI than are portrayed on the historic mine maps and cross-sections. The exact current configuration of underground workings cannot be determined based on available information.

During the preliminary bat survey, no airflow was observed at any of the mine openings. However, during the July 29, 2003 site visit by DEQ and E & E personnel, cool air was exhaling from the Tunnel No. 2 opening.

The ORNHIC data did not indicate any observations of bats within a two-mile radius of the Opalite Mine. Table 16 summarizes the observations made at each mine opening during the preliminary bat survey. The external data gathered at each mine opening did not indicate any visual signs of bats such as droppings, carcasses, or piles of insect parts. Photographic documentation of selected mine openings is presented in Appendix A.

Based on the data available, it cannot be determined whether the internal workings of the Opalite Mine currently provide, or could provide in the future, habitat suitable for bats.

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5

Exposure Assessment

In consultation with DEQ, E & E assessed risk to human health and ecological receptors. Results of the assessment are presented below.

5.1 Human Health Risk Screening

This section of the report presents a human health risk screening that evaluates the exposure setting of human receptors and exposure pathways on or near the site, and also evaluates if contaminants of interest (COIs) at the site are of sufficient concentration to be identified as contaminants of potential concern (COPCs) and warrant further investigation. The human health risk screening was performed in accordance with screening procedures outlined in the EPA's *Risk Assessment Guidelines for Superfund, Volume I, Human Health Evaluation Manual* (1989), DEQ's *Guidance for the Conduct of Deterministic Human Health Risk Assessments* (DEQ 2000), and other relevant guidance documents.

5.1.1 Conceptual Site Model and Identification of Exposure Pathways

The purpose of a conceptual site model (CSM) is to identify the human population in the locality of the Opalite Mine site that could come into contact with site-related contaminants. An exposure pathway describes the course a chemical takes from a source to an exposed individual. A complete exposure pathway must exist for a contaminant to pose a potential human health risk and must consist of the following four elements:

- A mechanism for contaminant release to the environment (e.g., release of volatile organic compounds to soil);
- An environmental transport medium for the released contaminant (e.g., infiltration and percolation to groundwater);
- A point of potential human contact with the contaminated medium (e.g., groundwater used as a source of domestic water); and
- An exposure route at the exposure point (e.g., ingestion of groundwater).

If an exposure pathway is incomplete, then it can be concluded that there is no current human exposure. Consequently, adverse effects to human health would not be expected under current conditions. However, changes in land use in the future may result in completion of some potential exposure pathways.

A CSM diagrammatically depicting sources, release mechanisms, exposure pathways, and receptors and current and potential future exposure pathways at the Opalite Mine site is presented in Figure 10. Complete major, potentially complete, and incomplete or minor exposure pathways are depicted in the CSM. Complete exposure pathways that are more likely to result in significant risks to potentially exposed receptors are considered major pathways. Minor exposure pathways are not expected to contribute significantly to risks to potentially exposed receptors. The exposure pathways and point of potential human contact are described below for each environmental medium of concern.

The potential contaminant transport pathways at the Opalite Mine are briefly discussed below.

- *Overland Runoff to Surface Waters.* Two primary overland pathways leading from mine sources to Mine Creek have been previously identified (Weston 2002). The northern overland flow path (estimated to be 0.3 mile long) originates near the waste rock pile at the Tunnel No. 1 portal, flows southward past the northern burned ore pile area and potentially from the area of glory hole, flows westward along an unpaved access road, and continues to the west-southwest until it reaches Mine Creek. The southern overland flow path (estimated to be 0.2 mile long) originates in the area near the southern burned ore pile, and runs southwest across an unpaved access road to Mine Creek. It is reported that flow from Mine Creek typically does not reach McDermitt Creek except during periods of high runoff, usually limited to one or two weeks per year (Weston 2002). Possible overland pathways from sources to the unnamed tributary to Cowboy Creek may exist, although such pathways have not been previously identified. Possible sources include waste rock dump located southeast of the glory hole (Weston 2002).
- *Direct Discharges from Mine Workings.* Direct discharge of water from mine workings may occur at the Opalite Mine, although no such discharges have been reported in previous investigations, and no evidence of such discharges were identified during the SI. Such discharges could be a source of AMD and elevated concentrations of metals in surface water, and, following percolation, in groundwater.
- *Leaching.* Elevated metals in contaminated soils, waste rock, ore, and burned ore may leach to groundwater.
- *Groundwater Discharge to Surface Waters.* Elevated metals leached from contaminated soils, waste rock, ore, and burned ore that could leach to shallow groundwater that may discharge to surface waters.

- *Use of calcines as roadbed material.* Processed ore from the burned ore piles been removed from the Opalite Mine ore processing area and used as roadbed material.
- *Wind Dispersion of Surface Soils.* Particulates with elevated metals concentrations at source areas may be transported through wind dispersion. Road material obtained from the burned ore piles may also be transported through wind dispersion.

5.1.2 Identification of Exposure Scenarios

Several exposure pathways are examined together to identify the potential exposure pathways in which a receptor may come in contact with site contaminants. The potential current and future exposure pathways and scenarios evaluated in the human health screening evaluation are described below.

Land use in the area of the Opalite Mine site consists mainly of livestock grazing. There are no residences or other structures within 4 miles of the site. Access to the sites is unrestricted (DEQ 2001). Due to the depth of ground water, and lack of receptors, the ground water pathway for human receptors does not appear to be significant, although possible shallow groundwater-surface water interactions have not been evaluated. It is assumed that some livestock watering and recreational activities such as fishing occur in streams associated with the mine (DEQ 2001).

Based on the information presented in previous reports, human receptors are anticipated to include:

- Occasional recreational users (hiking, camping, and recreational fishing); and
- Workers (minerals exploration).

Campers are reported to have camped at the mine sites and constructed fire rings with calcine and ore materials. Potentially complete and major exposure pathways to human receptors include:

- Incidental ingestion of, inhalation of, and dermal contact with contaminated surface soil and source material (e.g., ore, burned ore, waste rock, road material, and in situ mineralized material exposed within the mine workings);
- Inhalation of mercury volatilized from ore and/or burned ore materials used to construct camp fire rings; and
- Ingestion of fish caught from impacted streams.

5.1.3 Data Evaluation and Selection of Contaminants of Potential Concern

E & E reviewed analytical data from previous investigations (DEQ 2001 and Weston 2002) and this SI. Following data evaluation, soil and fish analytical results were screened to determine which COIs to retain as COPCs. COPCs were determined for each distinct area within the mine site. Soil and ore COPCs were identified at the waste rock area, ore processing area, glory hole, waste rock dump, northern burned ore pile, and southern burned ore pile. COPCs in fish tissue were identified for fish caught in Mine Creek, McDermitt Creek, and Hot Creek. Exposure to sediment and groundwater were not assumed to be complete or significant pathways for human receptors.

Only analytical data from fixed laboratory analyses were screened for COPCs. No results from field-screening (Lumex and XRF) analyses were included. Data validation results for fixed laboratory data were reviewed for usability in the risk screening. Results flagged with *R* qualifiers (indicating rejected results) were excluded from the screening procedure. The COPC screening summary tables are presented as Tables F-1 through F-9 of Appendix F.

COIs were designated as COPCs based on:

Frequency of Detection – The COPC screening tables summarize the frequency of detection for COIs in soil and fish tissue. If a COI is detected in less than 5% of the samples site-wide for a given medium, it is not retained for further evaluation as a COPC. No COIs were eliminated as COPCs based on the frequency of detection. In addition, no detection limits exceeded appropriate screening levels for non-detected analytes.

Background Concentrations – Inorganic (naturally-occurring) COIs that are detected at a maximum concentration less than the established background value are not retained for further evaluations as COPCs. Background soil concentrations were cited from Weston (2002), and are presented in the SI results tables for source materials. Background fish tissue samples were collected during the SI from Mine Creek (sample MC01) and McDermitt Creek (sample MT01) and were used to compare site fish tissue concentrations for COPC screening. The background fish tissue sample from Mine Creek (sample MC01) was used as comparison for the fish tissue sample from Hot Creek. The Hot Creek sample was taken downstream of the confluence of Mine Creek and Cowboy Creek. The Mine Creek background sample is the closest background sample upstream of the Hot Creek sample.

Concentration Risk Screen – COIs detected above background concentrations are screened against risk-based concentrations (RBCs) taking into account the potential for risk posed by exposure to individual COIs and multiple COIs in a given medium. For soil samples, the maximum detected soil concentration was compared to RBCs derived from EPA Region 9 PRGs for industrial surface soil

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(EPA 2003). It was assumed that the RBCs based on an industrial scenario would be generally protective of the occasional recreational user. Table 17 presents the RBCs used for the Opalite Mine SI risk screening.

For each COI exceeding background concentrations, the maximum detected concentration was divided by the respective RBC to generate the risk ratio for each individual COI. If the risk ratio was greater than one, then the COI was retained for further evaluation as a COPC. Next, the risk ratios for each COI were summed to generate a total risk ratio for soil. The individual risk ratio for each COI was divided by the total risk ratio for soil and compared to the inverse of the number of COIs. If the quotient was greater than one, then the COI was retained as a COPC due to multiple analytes in the media. Since human receptors may only be exposed to COIs in surface soil and fish tissue, screening for COPCs in multiple media was not needed.

Aluminum, calcium, iron, magnesium, potassium, and sodium are essential elements found in earth's crust and are not generally associated with human toxicity. Essential elements with available RBCs were screened as other COIs. Calcium, magnesium, potassium, and sodium do not have toxicity criteria or RBCs. If these COIs exceeded background concentrations they were tentatively identified as COPCs in Tables F-1 through F-9 of Appendix F. Calcium, magnesium, potassium, and sodium, can be omitted from further consideration because they are essential compounds and not associated with human toxicity (EPA 1989).

Samples of fish tissue were collected at five locations from three separate creeks associated with Opalite Mine. No EPA Region 9 PRGs exist for fish tissue. EPA Region III RBC tables include values for fish tissue (EPA 2004). The Region III RBCs are based on consumption of approximately 54 g/d of fish caught from the affected waterbody for 350 days a year. This is a conservative estimate of exposure to contaminants in fish at the site, and is appropriate for determining screening values for identifying COPCs in fish tissue. Therefore, the maximum concentration of contaminants in fish tissue from all samples collected near Opalite Mine were compared to the Region III RBC. There was no Region III RBC for lead; therefore lead was also retained as a COPC if it exceeded background concentrations.

5.1.4 Final List of COPCs

The final list of COPCs in soil or fish tissue for human health evaluation is provided in Table 18.

Arsenic and mercury are the primary human health COPCs identified in soil and ore at Opalite Mine. Arsenic and mercury were identified as human health COPCs at the waste rock area, ore processing area, and glory hole. Arsenic was the only identified COPC at the waste rock dump and the southern burned ore

pile. Arsenic and antimony were identified as COPCs at the northern burned ore pile.

Arsenic, both inorganic and arsenic (III), chromium, and mercury were identified as human health COPCs in fish tissue at Mine Creek and Hot Creek. In addition, lead was retained as a COPC in Mine Creek because the concentration exceeds the background level and no screening level was available. Mercury was the only human health COPC identified for fish tissue in McDermitt Creek.

5.2 Ecological Risk Assessment

This section presents the results of a Level I Scoping ERA and the Level II Screening ERA for the Opalite Mine site. The assessments were completed in accordance with DEQ's (2001b) *Guidance for Ecological Risk Assessment*. The purpose of a screening level ERA is to identify site-specific ecologically important receptors and relevant and complete exposure pathways, discuss the physiochemical and toxicological properties of each contaminant of potential ecological concern (CPEC), define ecological assessment endpoints, and develop a preliminary conceptual site model.

5.2.1 Site Conditions

Site conditions at the Opalite Mine are discussed in sections above. Mercury and other heavy metals are present at the site. Previous investigations have indicated that ecologically important receptors near the site include the federally listed threatened Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) and hybrids, which are present in McDermitt Creek downstream of the Opalite Mine. McDermitt Creek is listed as a 303d water quality limited stream for temperature (DEQ 2002).

5.2.2 Site Survey

In accordance with the ERA guidelines provided by DEQ (2001b), E & E performed an ecological site survey during the Phase I field activities. The survey evaluated potential ecological receptors and habitat, and focused on identifying habitats that may support threatened, endangered or sensitive species.

An E & E wildlife biologist performed the survey between December 16 and December 18, 2003. Weather conditions during the survey were dry and cold; temperatures ranged between 18°F and 32°F. The ground was covered with snow and the creeks were frozen at the time of the survey. The biologist walked the entire site and focused the survey on the mine sub-areas.

The Ecological Scoping Checklist, Evaluation of Receptor-Pathway Interactions, is provided in Appendix E. Photographic documentation from the December 2003 site survey is provided in Appendix A.

5.2.3 Contaminants of Interest

COIs include metals that are present in the vicinity of the site at elevated concentrations due to historical mining activities. The principal COI is mercury associated with mercury mine operations. Other COIs previously detected at the Opalite Mine include arsenic, cadmium, chromium (if present as chromium VI), copper, lead, nickel, selenium, and zinc.

5.2.4 Observed Impacts

Impacts to the shrub-steppe habitat observed during the December 2003 site survey were limited to historical activities associated with mining operations. Since the mine operations ceased, the majority of disturbance to the shrub-steppe habitat surrounding the mine has rebounded. Impacts to the shrub-steppe habitat are still noticeable within the former footprint of the mine. During mining operations several access roads were constructed throughout the area of the mine and permanently cleared areas of vegetation. The placement of the waste rock, waste rock dump, and the burned ore piles also impacted several acres of shrub-steppe habitat. Limited vegetation cover exists within the mine footprint compared to the surrounding area. In addition, dumping of several metal cans and other debris, were also observed in Mine Creek downstream of the mine.

Impacts to wildlife caused by the mining operations appear to be minimal. During the site survey several species were observed using the mine, and visual evidence of wildlife signs, such as tracks and scat, were observed within the mine footprint. The mine adits, shafts, and inclines/declines serve a variety of functions for wildlife using the area, such as foraging and retreat sites. The glory hole highwall also provides roosting sites and vantage points for wildlife, including two Great horned owls that were observed roosting within the crevices of the highwall.

Limited ecological impacts were observed during the December 2003 site survey. Observed impacts were associated with vegetation and wildlife on site and in the vicinity of the site. Ecological impacts observed at the site during previous investigations are discussed in detail in the *Opalite Mine Site Investigation Work Plan* (E & E 2003).

5.2.5 Ecological Features

A brief description of each primary ecological habitat identified during the December 2003 site survey is presented below.

- **Terrestrial-Wooded:** No wooded areas are within the former mine footprint. However, the banks of Mine Creek south of the Opalite Mine has limited riparian habitat. Species observed along the banks included willows, wild roses, and emergent wetland vegetation.
- **Scrub/Shrub/Grasses:** Shrub-steppe habitat is the main habitat found within the overall mine area. Vegetation cover is limited within the mine

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footprint when compared to the surrounding area due to former mining activities.

- **Ruderal:** The ruderal habitat includes those areas that have been impacted by mining activities, which have sparse shrub-steppe habitat or no vegetation present. These areas occur within the glory hole, the ore processing facility, former shop area, and the burned ore piles.
- **Aquatic – Flowing:** Mine Creek south of Opalite Mine was the nearest perennial surface water feature. The creek banks had limited riparian vegetation, which consisted of willows, wild roses, and associated emergent wetland vegetation. Where observed, the creek bed was very broad (approximately 40 feet bank to bank) and meandered southward toward its confluence with Cowboy Creek approximately 2 miles south of Opalite Mine. During the December 2003 survey the water in the creek was frozen. The estimated water's edge to water's edge distance was approximately 2 feet. The creek substrate appeared to be silty/clay overlain with cobbles. The banks of the creeks up to 3 feet above stream level had an 11-degree slope; as the creek bank height increased to 6 feet, the slope increased in slope to approximately 45 degrees.
- **Aquatic – Wetlands:** Wetlands within the area of the site were observed within the bed of Mine Creek, and totaled approximately 4 acres. Additional wetlands may be located within the creek south towards Cowboy Creek.

5.2.6 Potential Ecological Receptors

Ecologically important receptors, as defined by the Level I Scoping ERA (DEQ 2001b) guidance, at or in the vicinity of the Opalite Mine site are identified below. Cottontail rabbits and blacktail jackrabbits were observed during the December 2003 site survey. Tracks of a mountain lion and a woodrat nest were also observed during the site survey. Birds observed in the area include California quail, great horned owl, and chukar. Table 19 provides a list of species or habitats observed during the December 2003 site survey. Because the site survey was conducted during the winter, a limited number of species were observed. No vegetation was observed due to snow cover during the site survey.

Because the creeks were frozen at the time of the site survey, fish species were not observed. Previous investigations have indicated that the federally listed threatened Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) and hybrids are present in McDermitt Creek downstream of the Opalite Mine. The nearest sensitive environments to the site include Mine Creek and McDermitt Creek. The DEQ PA indicated that significant riparian vegetation existed in both creeks, and that small fish were present in Mine Creek (DEQ 2001a).

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In addition to Lahontan cutthroat trout, McDermitt Creek also contains brown trout, rainbow trout, speckled dace, Lahontan red-sided shiner, Lahontan sucker, mountain sucker, and Rainbow/Lahontan cutthroat trout hybrids. Speckled dace are located in Mine Creek both upstream and downstream of the Opalite Mine (Weston 2002).

Bat species could possibly use the underground workings for roosting, hibernating, rest stops during spring or fall migration, and/or rearing of young in the summer. A preliminary bat survey was conducted during the Phase I field activities (subsection 4.5). Results of the survey are inconclusive.

Ecologically important species documented at the site, either during the December 2003 site survey or as part of previous SIs comprise the site-specific ecological receptors for this screening level ERA, and are presented in Table 20.

5.2.7 Threatened, Endangered, Sensitive, or Rare Species

Information on rare, threatened, and endangered species within a 2-mile radius of the Opalite Mine site was obtained from the Oregon Natural Heritage Program in 2004 (ONHIC 2004) and is provided in Appendix G. The Oregon Natural Heritage Program listed the Western Greater Sage-grouse and Cooper's Goldflower as species of concern near the site, as identified by the U.S. Fish and Wildlife Service. The Western Greater Sage-grouse is also listed by the State of ODFW as a sensitive-vulnerable species. No threatened or endangered species were identified within the 2-mile radius of the site. The Western Greater Sage-grouse or Cooper's Goldflower were not observed during the December 2003 site survey.

The Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) is present in McDermitt Creek downstream of the Opalite Mine (Weston 2002). The Lahontan cutthroat trout is listed as a threatened species by the United States Fish and Wildlife Service (USFWS 2004). Although the Lahontan cutthroat trout was not identified by the Oregon Natural Heritage Program as habitating within a 2-mile radius of the site, it has been identified in McDermitt Creek downstream of the Opalite Mine, and therefore is considered in this assessment.

5.2.8 Relevant and Complete Exposure Pathway

The potential for ecological risk at the site is based on the presence of potential ecological receptors and potentially complete exposure pathways at or in the vicinity of the site, taking into consideration the physiochemical and fate and transport characteristics of the COIs.

Potential ecological exposure pathways for terrestrial and aquatic ecological receptors at the Opalite Mine are described below.

- *Terrestrial Receptors.* Terrestrial receptors, including invertebrates, birds, and mammals, may come into direct contact with contaminated sediments

(incidental ingestion and dermal) and surface water (ingestion and dermal). Terrestrial receptors may come into contact with soil contaminants through incidental ingestion of contaminated soil and/or source material. Exposure through dermal contact is limited to organic forms of metal contaminants that may cross the epidermal barriers. Terrestrial receptors may be exposed via inhalation of fugitive dust, although this exposure pathway is considered to be minor. Contaminants in bulk soil may partition into soil solution, making them available to plant roots. Plant roots may also take up impacted groundwater. Terrestrial receptors may also come into contact with bioaccumulative COIs (e.g., methylmercury and selenium) through ingestion of prey or food items.

- *Aquatic Receptors.* Aquatic receptors may be exposed to contaminants in surface water and sediment through osmotic exchange, respiration, or ventilation of surface waters (ingestion and dermal). Exposure by aquatic receptors includes both chronic and acute exposures. Acute exposures are more likely to occur during periods of high runoff, such as may occur in Mine Creek during the spring. Aquatic receptors may also come into contact with bioaccumulative COIs (e.g., methylmercury and selenium) through ingestion of prey or food items. Contaminants in surface water or sediment may be taken up by plant roots or have direct contact with plants.

5.2.9 Candidate Assessment Endpoints

An assessment endpoint is defined as an explicit expression of a specific ecological receptor and an associated function or quality that is to be maintained or protected. Assessment endpoints focus the evaluation on the guild or community that might be affected adversely by exposure to a CPEC. Based on the ecological receptors identified at the Opalite Mine, the following candidate assessment endpoints were identified:

- Protection of Lahontan cutthroat trout of survival, growth, and reproduction associated with exposure to heavy metals;
- Protection of structure and function of terrestrial plant communities associated with exposure to heavy metals;
- Protection of survival, growth, and reproduction of terrestrial mammals associated with exposure to heavy metals (herbivore, invertivore, and carnivore populations);
- Protection of survival, growth, and reproduction of avian populations associated with exposure to heavy metals; and
- Protection of survival, growth, and reproduction of invertivore populations associated with exposure to heavy metals.

5.2.10 Known Ecological Effects

Documented toxicological effects of each COI are summarized below.

Aluminum. Aluminum is the third most abundant element of the earth's crust. It can be highly toxic to aquatic biota under some circumstances, but its toxicity is strongly dependent on pH, water hardness, and organic matter content. (Sample et al. 1997)

Antimony. Antimony is a naturally occurring metal existing in valence states of 3 and 5. Inorganic antimony and a few trivalent antimony compounds are the most significant forms with respect to exposure potential and toxicity. (Sample et al. 1997)

Arsenic. Arsenic is a naturally occurring metal found in air and all living organisms. It is sparingly soluble in water. It occurs as two forms in ambient media. Arsenic (III) is usually the most toxic; arsenic (V), a form in which bioavailability and toxicity are dependent upon the oxidation state and temperature. The relative toxicities of the various forms of arsenic vary from species to species. Arsenic may be released into aquatic ecosystems by anthropogenic sources including the manufacture and use of arsenical defoliants and pesticides, electric generating stations, mineral and strip mines, and natural leaching of the soils. Arsenic is known as one of the most toxic elements in fish with acute exposures resulting in immediate death. Arsenic is not readily bioconcentrated by fish or biomagnified up the food chain. Target organs include the liver, skin, and muscle. (Sample et al. 1997)

Barium. Barium is found in the more common mineral forms barite and witherite. Approximately 400 mg/kg of barium is found in the earth's crust. Some plants accumulate barium from the soil. (Sample et al. 1997)

Calcium. Calcium is the third most abundant metal of the earth's crust. It is an essential nutrient and occurs in surface waters primarily as calcium carbonate. Calcium, as dissolved cations in fresh water, is chiefly responsible for water hardness, and reduces the toxicity of several other metals in aqueous solution. (Sample et al. 1997)

Cadmium. Cadmium occurs predominately in the form of free divalent cations in most well-oxygenated, low-organic-matter, fresh waters. However, both particulate matter and dissolved organic matter can bind cadmium in biologically unavailable forms. There is no evidence that cadmium is a biologically essential or beneficial element. Cadmium toxicity is reduced with increased water hardness. Aquatic organisms are able to bioconcentrate cadmium. There is evidence that only the lower trophic levels can biomagnify the element. (Sample et al. 1997)

Chromium. Chromium occurs in the environment as either chromium (III) or chromium (VI). Trivalent chromium is an essential metal in animals, playing an important role in insulin metabolism. Hexavalent chromium is more toxic than

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chromium (III) because of its high oxidation potential and the ease with which it penetrates biological membranes. Chromium (III), the predominant form in the environment, exhibits decreasing solubility with increasing pH. In most soils, chromium is present primarily as precipitated chromium (III), which is not bioavailable and which has not been known to biomagnify through food chains in its inorganic form. Chromium is naturally released into the environment through the weathering of soils. (Sample et al. 1997)

Copper. Copper occurs in natural water primarily as the divalent cupric ion in free and complexed forms. Copper is a minor nutrient for both plants and animals at low concentrations, but is toxic to aquatic life at only slightly higher concentrations. Common copper salts are used as components of ceramics and pyrotechnics, for electroplating, and for numerous industrial applications. Elemental copper is insoluble in water. The largest anthropogenic releases of copper to the environment result from mining operations, agriculture, solid waste, and sludge from sewage treatment plants. Copper is not known to be appreciably bioaccumulated by fish, but some algae and bivalve mollusks do bioconcentrate or bioaccumulate copper. (Sample et al. 1997)

Nickel. Nickel is a very abundant natural element found in all soils. Nickel can combine with other elements such as chlorine, sulfur, and oxygen to form nickel compounds that dissolve fairly easily in water. Much of the nickel in the environment is found with soil and sediments because nickel attaches to particles that contain iron or manganese. Nickel does not appear to collect in fish, plants, or animals used for food. (ATSDR 1997)

Mercury. Mercury is a naturally occurring metal that occurs in several forms. Inorganic mercury enters the air from mining ore deposits, burning coal and mercury-bearing waste, and from manufacturing. Methylmercury can be formed in water and soil by bacteria. Mercury enters the water or soil from natural deposits, disposal of wastes, and volcanic activity. Methylmercury biomagnifies in the tissue of fish. (ATSDR 1999)

Selenium. Selenium is a naturally occurring element that is distributed widely in most rocks and soils. In nature it is combined with sulfide or with silver, copper, lead, and nickel. Selenium can enter the atmosphere from burning coal and oil, after which selenium dust eventually settles over the land and water. Selenium also enters water from rocks and soil, and from agricultural and industrial waste. Insoluble forms of selenium will remain in soil, but soluble forms are very mobile and may enter surface water from soils. Selenium may accumulate up the food chain. (ATSDR 2003)

Vanadium. Vanadium can be found in the earth's crust in rock, including some iron ores, and petroleum deposits. Vanadium mainly enters the environment from natural sources and stays bound in the soil for a long time. It does not dissolve

readily in water. Low levels have been found in plants, but it is not likely to build up in the tissues of animals. (ATSDR 1995)

Zinc. Zinc is one of the most common elements in the earth's crust. It is found in air, soil, and water, and is present in all foods. Some zinc is released into the environment from natural processes, but most comes from human activities like mining, steel production, coal burning, and burning of waste. It attaches to soil, sediments, and dust particles from the air. Depending on the type of soil, some zinc compounds can move into the groundwater and surface water bodies. Most of the zinc in soil stays bound to soil particles and does not dissolve in water. Zinc can accumulate in fish and other organisms but does not accumulate in plants. (ATSDR 1995)

5.2.11 Contaminants of Potential Ecological Concern

CPECs were determined following the steps outlined below.

Frequency of Detection - COIs detected in less than 5% of the samples or greater than the background concentration are eliminated as CPECs. No analytes were eliminated due to frequency of detection.

Background Concentrations – Inorganic COIs that are detected at a maximum concentration less than the established background value are not retained for further evaluation as COPCs.

Background soil concentrations were cited from Weston (2002) and are provided in the COPCs screening tables.

Background sediment samples for comparison to Mine Creek samples were collected during the Phase II field event from Mine Creek (MC01) and the west tributary of Mine Creek (OPWM01), and in 2002 from Mine Creek (ST008; Weston 2002). Background sediment samples for McDermitt Creek were collected during the Phase II field activities (MT01), and in 2002 (ST003; Weston 2002). A single background sediment sample was collected during Phase II field activities from Cowboy Creek (OPCC01). The background sample from Cowboy Creek was used for comparison for the sediment sample collected from Hot Creek. The Hot Creek sample was taken downstream of the confluence of the Mine Creek and Cowboy Creek. The Cowboy Creek background sample is the closest background sample upstream of the Hot Creek sample.

Background surface water samples were taken from Mine Creek (MC01) and McDermitt Creek (MT01). The background sample for Mine Creek was used for comparison to the Hot Creek sample data.

Concentration Risk Screen – Maximum concentrations were used as the exposure concentration for this evaluation. There were not sufficient samples at discrete locations to calculate the 90% upper confidence limit. For each COI that

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exceeded background concentrations, the maximum detected concentration was divided by the respective SLV to generate a risk ratio. DEQ Level II Ecological SLVs are presented in Table 17. If a risk ratio was greater than 1 for an individual assessment (e.g., used for threatened or endangered species) or 5 for a population assessment, then the COI was retained for further evaluation as a CPEC. The risk ratios for each COI in the individual medium were summed to generate a total risk ratio for that medium. The risk ratio for each COI was divided by the total risk ratio for the medium and compared to the inverse of the number of COIs. If the quotient was greater than 1 for an individual assessment or 5 for a population assessment, then the COI was retained as a COPC due to multiple analytes at a site in a given media.

No terrestrial threatened or endangered species were identified in the vicinity of the Opalite Mine; therefore, soil screening was evaluated at the population level. The federally listed threatened Lahontan cutthroat trout was identified in McDermitt Creek downstream of Opalite Mine. Therefore, surface water and sediment in McDermitt Creek were screened at the individual level. Surface water and sediment results for all other water bodies were screened at the population level.

The results of the CPEC screening at Opalite Mine are summarized below. Summary CPEC tables are presented as Tables H-1 through H-15 of Appendix H.

The maximum concentrations in soil were compared to background concentrations and the lowest values of the DEQ Level II Ecological SLVs for terrestrial receptors (plants, inverts, birds, and mammals). Soil CPECs were identified for each sub-area at Opalite Mine.

Soil CPECs by sub-areas are identified below and in Appendix H, Tables H-1 through H-6:

- **Waste Rock.** CPECs include antimony, arsenic, iron, mercury, and vanadium (Table H-1);
- **Ore Processing Area.** CPECs include aluminum, arsenic, barium, chromium, iron, mercury, nickel, vanadium, and zinc. Although calcium, magnesium, and sodium concentrations exceeded the background concentrations, these elements have no SLV, and are essential metals that are generally not associated with ecological toxicity (Table H-2).
- **Glory Hole.** CPECs include antimony, arsenic, chromium, mercury, and vanadium. The essential metals calcium and magnesium exceeded the background concentrations but no SLV exists (Table H-3).
- **Waste Rock Dump.** CPECs include aluminum, arsenic, chromium, iron, mercury, and vanadium. Calcium, magnesium, and sodium exceeded the background concentrations, but no SLV exists (Table H-4).

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- **Northern Burned Ore Pile.** CPECs include antimony, arsenic, iron, mercury, and vanadium. Calcium and sodium exceeded the background concentrations, but no SLV exists (Table H-5).
- **Southern Burned Ore Pile.** CPECs include antimony, arsenic, mercury, and vanadium. Calcium, magnesium, and sodium exceeded the background concentrations, but no SLV exists (Table H-6).

The maximum concentrations in sediment were compared to background concentrations and the lowest values of the DEQ Level II Ecological SLVs for freshwater receptors and bioaccumulation. Sediment CPECs were identified for each water body potentially impacted by the Opalite Mine.

Sediment CPECs for individual water bodies are tentatively identified below and in Appendix H, Tables H-7 through H-10:

- **Mine Creek.** CPECs include mercury. Aluminum, barium, calcium, magnesium, potassium, and sodium concentrations exceeded background concentrations, but no SLVs exist. Each of these analytes except barium is an earth crust metal and generally not associated with ecological toxicity (Table H-7).
- **McDermitt Creek.** CPECs include arsenic, cadmium, nickel, and selenium. Aluminum, barium, calcium, cobalt, iron, magnesium, and sodium exceeded the background concentrations, but no SLVs exist (Table H-8).
- **Cowboy Creek.** CPECs include arsenic, cadmium, mercury, and zinc. Aluminum, magnesium, potassium, sodium, and vanadium exceeded the background concentrations, but no SLVs exist (Table H-9).
- **Hot Creek.** CPECs include cadmium, mercury, and zinc. Aluminum, barium, calcium, cobalt, magnesium, potassium, sodium, and vanadium exceeded the background concentrations, but no SLVs exist (Table H-10).

The maximum concentrations in surface water were compared to background concentrations and the lowest values of the DEQ Level II Ecological SLVs for receptors that may come in contact with freshwater (aquatic receptors, birds, and mammals). CPECs were identified for water bodies potentially impacted by the Opalite Mine.

Surface water CPECs for individual water bodies are identified below and in Appendix H, Tables H-11 through H-13:

- **Mine Creek.** No CPECs were identified (Table H-11).
- **McDermitt Creek.** CPECs include arsenic, copper, nickel, and vanadium. Calcium and copper were identified as CPECs due to the presence of multiple CPECs in surface water, but they did not exceed the SLVs. The concentrations of calcium and copper were only slightly higher than the background concentrations. Calcium and copper may be

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tentatively identified as CPECs at the site due to the limited information on background concentrations (Table H-12).

- **Hot Creek:** No CPECs were identified (Table H-13).

Both surface water and sediment data are available for Mine Creek, McDermitt Creek, and Hot Creek. If a COI was detected in both surface water and sediment, it was retained as a CPEC for multiple media evaluation if the sum of the risk ratio for the COI in sediment and surface water were greater than 1 for an individual assessment (McDermitt Creek only) and 5 for a population assessment. Results of screening for CPECs in multiple media are presented in Appendix H, Table H-14. Based on multiple media screening, cadmium, nickel, and selenium were added as surface water CPECs for McDermitt Creek, and cadmium, mercury, and zinc were added as surface water CPECs for Hot Creek.

The final list of CPECs is presented in Table 21.

5.2.12 Ecological Conceptual Site Model

An ecological CSM for the Opalite Mine was prepared in accordance with DEQ's *Guidance for Ecological Risk Assessment* (DEQ 2001b). The CSM describes the sources, contaminant release mechanisms, exposure points, and exposure routes to receptors. The ecological CSM is presented diagrammatically in Figure 10.

6

Time-Critical Removal Action Assessment of Physical Hazards

In consultation with DEQ, physical hazards at the site have been identified as an immediate concern for public safety. E & E assessed these physical hazards, and has prepared a recommended approach to mitigate the threat to public safety, presented below.

Physical hazards identified at the Opalite Mine site include highwalls and mine openings resulting from historic mining operations. The highwalls and openings to shafts, inclines/declines, and adits may pose a safety hazard to the public. Specific safety concerns include falling and collapse. The highwalls are located along the northern and eastern perimeter of the glory hole, and at the northwestern ends of the northeast trench and southwest trench located east of the glory hole (Figures 2 and 9). Mine openings are present at locations throughout the site. Numerous openings are located within the footprint of the glory hole (Figure 9). The mine openings are described in Table 16. Photographic documentation of selected mine openings and highwalls is presented in Appendix A.

E & E recommends minimizing public exposure to these physical hazards by limiting access using fences and signage. E & E proposes construction of barbed-wire fences in two areas – the glory hole and the area of the northeast and southwest trenches (see Figure 11). In the glory hole area, the recommended fence alignment encloses the entire glory hole area, and thus limits access to the highwalls located along the northern and eastern edges of the glory hole, as well as the mine openings located within the footprint of the glory hole. A gate would permit authorized access to the enclosed area. In the area of the northeast and southwest trenches, the recommended fence alignment is not fully enclosed. This alignment would limit, but not preclude, access to the steepest portions of the trench highwalls as well as a shaft located near the highwall edge (GH01019). The recommended fence alignment is presented in Figure 11.

The recommended fencing design includes commercial grade components and one gate for enclosure access. The recommended fence is not designed to be a security fence.

6. Time-Critical Removal Action Assessment

E & E previously prepared a design for warning signs that DEQ prepared and posted at selected locations at the site. E & E recommends that additional signage of a similar design be attached to the fencing.

As discussed above, access to those mine openings located within the recommended glory hole fence enclosure would be limited. Access to those mine openings located outside the fenced enclosure would remain unlimited. It is recommended that mine openings not located within the fenced enclosure be closed individually in the future. It may be desirable to individually close the openings located within the fenced enclosure in the future as well. Prior to closing any mine openings, a bat survey should be completed to determine which, if any, of the underground mine workings may provide suitable bat habitat. E & E completed a preliminary bat survey. Results of the preliminary survey, presented in subsection 4.5, are not conclusive.

7

Removal Assessment

No interim removal actions to address chemical hazards to human health or the environment are recommended at this time. Although COPCs and CPECs were identified as part of the human health and ecological risk screening, respectively, insufficient information is currently available to adequately evaluate risk to human and ecological receptors. Specifically, there is not currently enough information on background metals concentrations, and impacts to surface water resources are not sufficiently understood. It is recommended that risk to human health and ecological receptors be further evaluated before any additional risk management decisions are made.

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8

Summary and Recommendations

Results of the SI and previous investigations indicate on-site metals contamination over a broad area, including the glory hole, ore processing area, burned ore piles, waste rock area, and dump. Results also indicate that on-site metals contamination may be impacting downgradient surface water, sediment, and fish.

COPCs that may pose a risk to human health include antimony, arsenic, and mercury in site sources, and organic arsenic, arsenic (III), chromium, lead, and mercury in fish. CPECs in site sources that may pose a risk to ecological receptors include: aluminum; antimony; arsenic; barium; chromium; iron; mercury; nickel; vanadium; and zinc. CPECs identified in sediment include arsenic, cadmium, mercury, nickel, selenium, and zinc. CPECs identified in surface water include arsenic, cadmium, mercury, nickel, selenium, vanadium, and zinc.

No interim removal action measures to address the metals contamination are recommended at this time. The broad area over which COPCs and CPECs are located would require a major removal effort based on screening levels alone. There is insufficient information at present to establish site-specific, risk-based cleanup levels. Background metals concentrations are not well characterized, and the risks posed by site-related COPCs/CPECs has not been adequately assessed. It is recommended that risk to human health be further evaluated in order to make risk management decisions. Based on the findings of the Level II Screening it is recommended that a baseline ERA be conducted for soil, sediment, and surface water at the site.

To address physical hazards at the site, E & E recommends installation of fencing and signage to limit access to highwalls and most of the mine openings. Closure of the remaining mine openings is recommended in the future. Prior to such closure, a bat survey is recommended to determine if suitable habitat for bats exists within the underground mine workings.

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A

Photographic Record

B

**Laboratory Data Package
Summary and Quality Assurance
Memoranda**

C

Field Screening vs. Fixed Laboratory Results Correlation Plots

D

Mercury in Sediment vs. Stream Distance Plots

E

Ecological Level I Documentation

F

Human Health Risk Screening Tables

G

Oregon Natural Heritage Program Information

H

Compounds of Potential Ecological Concern Tables

